



Allen, W., Corey, R., Oatley, P., Sessions, R., Baldwin, S. A., Radford, S. E., Tuma, R., & Collinson, I. (2016). Two-way communication between SecY and SecA suggests a Brownian ratchet mechanism for protein translocation. *eLife*, 5, [e15598].
<https://doi.org/10.7554/eLife.15598>

Publisher's PDF, also known as Version of record

License (if available):
CC BY

Link to published version (if available):
[10.7554/eLife.15598](https://doi.org/10.7554/eLife.15598)

[Link to publication record in Explore Bristol Research](#)
PDF-document

This is the final published version of the article (version of record). It first appeared online via eLife at <https://elifesciences.org/content/5/e15598>. Please refer to any applicable terms of use of the publisher.

University of Bristol - Explore Bristol Research

General rights

This document is made available in accordance with publisher policies. Please cite only the published version using the reference above. Full terms of use are available:
<http://www.bristol.ac.uk/red/research-policy/pure/user-guides/ebr-terms/>

Special Section: Moving from Citizen to Civic Science to Address Wicked Conservation Problems

Justin Dillon*, Robert B. Stevenson and Arjen E. J. Wals***, Guest Editors******

** Graduate School of Education, University of Bristol, 35 Berkeley Square, Bristol BS8 1JA, United Kingdom*

*** The Cairns Institute, James Cook University, P.O. Box 6811, Cairns, Qld 4870, Australia*

**** Education & Competence Studies, Wageningen University, Hollandseweg 1, 6706 KN Wageningen, The Netherlands, email arjen. wals@wur.nl and Faculty of Education, University of Gothenburg, Sweden*

*****The authors contributed equally to this essay and are thus listed alphabetically.*

Introduction

In a recent paper (Wals et al. 2014), we, the editors of this special section, argue for a new model of collaborative research among scientists, educators, and the public to strengthen links between science and society with a focus on place and identity. We envisioned citizen science (CS) as a mechanism for enabling the convergence of science and society and for, ultimately, more effective processes of public engagement and learning that could lead to meaningful socioecological outcomes.

Bonney et al. (2014), called for strategic investments and more coordination to help CS reach its full potential. We developed their ideas by assuming not only that any qualitative and quantitative data gathered through CS initiatives can provide useful input to conservation science, but also can simultaneously empower citizens to engage in ongoing debates about local and global environmental and sustainability issues.

This special section follows an international call for contributions to these topics and further examines them by presenting research that addresses a number of key questions. First, to what extent does the use of CS precipitate conservation education outcomes in terms of citizens' improved knowledge, understanding, and engagement in local and global conservation issues? Second, are data generated by CS of sufficient quality to be useful for conservation science? Third, what methodological issues influence the effectiveness of CS initiatives in terms of their impact on learning and on conservation outcomes, and how can they be addressed?

From 11 papers in this special section, we guest editors developed a richer understanding of CS and conservation. The authors featured in this section engage with the questions above, but they do more: they raise critical questions about the nature of citizen science. In this introduction, based on our reading of the papers, we generate a heuristic for positioning CS that may stimulate future research and practice. We first introduce this heuristic or conversation tool and then position the papers in the array that emerges.

There are many reasons for involving citizens in the science needed to advance and strengthen conservation of the world's biodiversity. Citizen science is not new (Silvertown 2009), but it is receiving renewed attention partly as a result of new opportunities arising from citizens' access to information and communication technologies that offer new opportunities for data collection, crowd sourcing, sharing, and interaction. One can distinguish several varieties of CS that can be placed on a continuum from highly instrumental forms driven by experts or science to more emancipatory forms driven by public concern. The variations explain why citizens participate in CS and why scientists participate too. To advance the conversation, we distinguish between three strands or prototypes: science-driven CS, policy-driven CS, and transition-driven *civic science*.

Science-Driven Citizen Science

Much CS involves contributions to data sets. This is often the case when there are not enough researchers available and increasing the number of professional researchers is too expensive; novices can relatively easily gather valuable data. With sufficient volunteers and some basic training and measures to safeguard reliability, citizens can contribute to scientific knowledge in a significant way. Science-driven CS is at the instrumental end of the continuum. Typically, scientists set the research agenda and determine the tasks (which often involves some form of monitoring), whereas volunteers are instructed to collect and share data immediately, often using prescribed protocols. The scientists then analyze the data and, finally, interpret their meaning and potential significance. It is the scientists who report the findings at conferences and in peer-reviewed journals, although they usually find a way to share results with the volunteers.

Policy-Driven Citizen Science

Both the world of governance and the world of science may see merit in actively engaging citizens in key issues (e.g., climate change and loss of biodiversity). For scientists it is important that the research is both relevant to citizens in addressing real-world issues and engages people, especially young people, in scientific inquiry to make them scientifically literate and interested in supporting research. For policy makers and local governments, public participation in science can create support for particular policies, which might support conservation measures. Scientists play a key role in defining the issues at stake and determining what research needs to be done and how, but there is some flexibility for citizens' own ideas.

Transition-Driven Civic Science

This relatively new approach can be traced back to a postnormal science perspective (Ravetz 2004), which assumes the issues at stake, such as climate change or loss of biodiversity, are ill-defined, highly contextual, and ambiguous. To deal with these wicked issues, one needs to realize that citizens have or need to have agency; scientific knowledge includes other types of knowledge, for instance, indigenous knowledge and local knowledge; and actions to improve a situation require social learning between the multiple stakeholders affected by an issue. With these realizations, CS becomes civic science in that the questions being addressed, the ways

data are collected and knowledge and meaning are constructed, and the course of action to be taken are co-created and therefore not driven by science or policy making but rather supported by science and new forms of governance. Civic science tends to focus on involving scientists as one group of the stakeholders among many in a joint learning process around so-called wicked problems (Fig. 1).

<insert figure 1 about here>

Over 20 years ago, Ulrich Beck (1992) introduced the idea that humans are living in a “risk society” typified by insecurity and unpredictability stemming from unintentional and partly unforeseen changes to socioecological systems. We are increasingly faced with wicked problems—poverty, equality, well-being, and sustainability—problems and challenges for which there are no ready-made solutions because of incomplete or contradictory knowledge and incompatible or conflicting perspectives or value positions (Barnett 2012).

Wicked problems have become more pressing with rising global temperatures and sea levels; rapid increases in loss of biodiversity, from deforestation and other forms of habitat destruction and degradation; depletion of natural resources; and contamination of drinking water. These kinds of environmental concerns are causing social and economic problems such as the displacement and forced migration of human populations vulnerable to the impact of climate change and conflicts over access to diminishing resources. These problems threaten to disrupt social and political stability on a global scale and lead to even greater inequality and poverty because the poorest populations are the most vulnerable to these damaging ecological forces.

The resolution or amelioration of wicked problems also cannot occur without explicitly challenging the values underlying such basic questions as what is important, what matters, to whom, and what constitutes knowledge, power, and fairness? The focus is not so much on doing the things we do better (i.e., making science more efficient in dealing with relatively simple or complex problems for which there is some robust knowledge available); rather, the focus is on doing better things altogether by transitioning to new forms of science and civic engagement that can deal with emerging, wicked sustainability challenges. This transition perspective can be found on the emancipatory side of the continuum, which emphasizes multi-stakeholder dialogue, capacity building, agency, co-creation, and reflexivity (Bunders et al. 2010).

The characteristics of a risk society and of wicked problems correspond with the characteristics of most conservation problems, such as addressing biodiversity loss (Game et al. 2014): high levels of complexity, unpredictability, uncertainty, contestation, and continuous change. Science and society are increasingly acknowledging wicked problems, so what role might CS play in improving the understanding of such problems and in helping both science and society cope better with inevitable ambiguities, complexities, and uncertainties? And, more specifically, what approaches to CS best respond to the conditions of a risk society and the challenges of wicked conservation problems?

A well-known typology identifies three types of CS based on the amount and kind of

public participation in the project design (Bonney et al. 2009). The most participatory type is co-created partnerships, and it engages citizens in all facets of the research from identifying research questions to designing studies and interpreting (Wiggins & Crowston 2011). This participatory mode of CS is reminiscent of Hackley's (2013) notion of community science in which citizens use scientific methods to produce knowledge about a local issue and bring about change.

We combined Jickling and Wals' (2008) heuristic for understanding environmental and sustainability education (Jickling & Wals 2008) and M. Fox and R. Gibson's problem typology (Fig. 1) to provide an overview of the different possible configurations of citizen science (Fig. 2). The heuristic has 2 axes. We call the horizontal axis the participation axis, along which extend the possibilities (increasing from left to right) for stakeholders, including the public, to participate in setting the agenda; determining the questions to be addressed; deciding the mechanisms and tools to be used; choosing how to monitor, evaluate, and interpret data; and choosing the course of action to take. The vertical (goal) axis shows the possibilities for autonomy and self-determination in setting goals and objectives. The resulting quadrants correspond to a particular strand of citizen science. All three occupied quadrants are important and legitimate. We were unable to identify an approach to CS that fits the lower left quadrant and challenge readers to make suggestions. The point is that it is important to first reflect on the type of problem in order to determine what strand or form of CS or, in case of the lower right quadrant, civic science is most suitable.

<insert figure 2 about here>

With one exception, all the articles in this special section describe CS projects that are relatively easy to position in either the science-driven quadrant or the policy-driven quadrant (Fig. 2).

Chase and Levine (2016 [this issue]) present a framework of resource characteristics for evaluating and de and creating meaning from the findings. This view of citizen science potentially signifies a shift in the way science is typically done (Wiggins & Crowston 2011). This participatory mode of CS is reminiscent of Hackley's (2013) notion of community science in which citizens use scientific methods to produce knowledge about a local issue and bring about change.

Dolrenry et al. (2016 [this issue]) describe a citizen science program involving traditional Maasai warriors in rural Africa. The participants were trained to take part in community-based conservation and demographic monitoring of a persecuted African lion (*Panthera leo*) population. The program produced positive outcomes in terms of improved scientific knowledge and desirable conservation outcomes. The study fits in the policy-driven CS quadrant (Fig. 3).

<insert figure 3 about here>

Haywood et al. (2016 [this issue]) examine performance data from several hundred participants in a scientifically rigorous CS program, looking for measurable change in and links between understanding and action. They propose a model of conservation

literacy, which through encouraging individuals to develop a personalized prioritization schema makes it more likely they will engage in conservation action. The goals of the CS program described are predetermined, but, to some extent, the study has elements of science-driven and policy-driven CS in that the end result of the project is a better understanding of conservation and more empowered citizens.

Jordan et al.'s (2016 [this issue]) article is, perhaps, the odd one out in the collection in that the authors examined collaborative science, which they describe as "a highly interactive form of citizen science." They discuss organizing citizen science "around local issues and engaging in iterative, collaborative, and adaptive learning." They term this kind of endeavor *collaborative science*. Of all the papers in the section, it is the only one that can be placed in the transition-driven CS quadrant (Fig. 3).

Predavec et al.'s (2016 [this issue]) study of koala (*Phascolarctos cinereus*) populations involved drawing on community wisdom through email surveys. They conclude that such studies "have the benefit of engaging a broad section of the community in conservation research and education and therefore in the political process of conserving species." Such an outcome would place the koala program in the policy-driven CS quadrant (Fig. 3), although the extent to which the participating communities would appreciate the purpose of taking part in the exercise is not clear from the study.

Schmiedel et al. (2016 [this issue]) compare the parataxonomist and paraecologist approach with traditional citizen science. Paraecologists and parataxonomists are resident professionals with local knowledge who lack formal academic training. They develop their ecological or taxonomic knowledge in situ. Based on their studies of CS programs in Costa Rica, India, Papua New Guinea, and southern Africa, Schmiedel et al. (2016) believe parataxonomists and paraecologists have the potential to contribute to scientific research. They also have a role in local capacity development and enhancing communication between local people and scientific communities. As such, although the programs studied all fit within the science-driven CS quadrant, the parataxonomists and paraecologists may have a key role in facilitating transition-driven civic science.

Swanson et al. (2016 [this issue]) describe a sciencedriven methodological innovation for producing "accurate, reliable data from untrained, nonexpert volunteers." They designed a human–computer interface to help guide people with no background knowledge through the process of animal identification from 48 possible species and taxonomic groups while providing a rapid route to classification for more knowledgeable participants. This study is a good example of a science-driven CS project.

Turnhout et al. (2016 [this issue]) examine how data validation in projects in the Netherlands and the United Kingdom acts to connect the diverse people and practices in natural-history citizen science networks. Although they refer to the need for biodiversity data "to inform policy and management," the projects described are primarily science-driven.

Vallabh et al. (2016 [this issue]) use a citizen science epistemic cultures heuristic, which they developed to map 56 citizen science projects in southern Africa. They focus on

whether the learning that takes place during the projects is, in effect, science-driven or driven by what the authors term “matters of concern.” Vallabh et al. (2016) argue that “science becomes a key feature of learning-centered and ethically motivated civic practice.

Literature Cited

- Barnett R. 2012. Learning for an unknown future. *Higher Education Research & Development* **31**:65–77.
- Beck U. 1992. *Risk society: towards a new modernity*. Volume **17**. Sage, London.
- Bonney R, Cooper CB, Dickinson J, Kelling S, Phillips T, Rosenberg KV, Shirk J. 2009. Citizen science: a developing tool for expanding science knowledge and scientific literacy. *BioScience* **59**:977– 984.
- Bonney R, Shirk JL, Phillips TB, Wiggins A, Ballard HL, Miller-Rushing AJ, Parrish JK. 2014. Next steps for citizen science. *Science* **343**:1436– 1437.
- Bunders JF, Broerse JE, Keil F, Pohl C, Scholz RW, Zweekhorst MB. 2010. How can transdisciplinary research contribute to knowledge democracy? Pages 125–152 in *Knowledge democracy*. Springer, Berlin.
- Chase SK, Levine A. 2016. A framework for evaluating and designing citizen science programs for natural resources monitoring. *Conservation Biology*: in press.
- Dolrenry S, Hazzah L, Frank LG. 2016. Conservation and monitoring of a persecuted African lion population by Maasai warriors. *Conservation Biology*: in press.
- Game ET, Meijaard E, Sheil D, McDonald-Madden E. 2014. Conservation in a wicked complex world; challenges and solutions. *Conservation Letters* **7**:271–277.
- Gibson R, Fox M. 2013. *Simple, Complex and Wicked Problems*. Available from <http://mofox.com/pdf/simple,complex,wicked.pdf>.
- Hackley M. 2013. Citizen science and volunteered geographic information: Overview and typology of participation. Pages 105–122 in Sui D, Elwood S, editors. *Crowdsourcing geographic knowledge*. Springer, The Netherlands.
- Haywood BK, Parrish JK, Dolliver J. 2016. Place-based and data-rich citizen science as a precursor for conservation action. *Conservation Biology*: in press.
- Jickling B, Wals AE. 2008. Globalization and environmental education: looking beyond sustainable development. *Journal of Curriculum Studies*, **40**:1–21.
- Jordan R, Gray S, Sorensen A, Newman G, Mellor D, Newman G, HmeloSilver C, LaDeau S, Biehler D, Crall A. 2016. Studying citizen science through adaptive management and learning feedbacks as mechanisms for improving conservation. *Conservation Biology*: in press.
- Predavec M, Lunney D, Hope B, Stalenberg E, Shannon I, Crowther MS, Miller I. 2016. The contribution of community wisdom to conservation ecology. *Conservation Biology*: in press.
- Ravetz J. 2004. The post-normal science of precaution. *Futures* **36**:347– 357.
- Schmiedel, et al. 2016. Contributions of paraecologists and parataxonomists to research, conservation, and social development. *Conservation Biology*: in press.
- Silvertown J. 2009. A new dawn for citizen science. *Trends in Ecology & Evolution* **24**:467–471.
- Swanson A, Kosmala M, Lintott C, Packer C. 2016. A generalized approach for producing, quantifying, and validating citizen science data from wildlife images. *Conservation Biology*: in press.

Tabara JD. 2014. Social learning and environmental change. Pages 253– 265 in Lockie S, Sonnefeld D, Fisher D, editors. Routledge handbook of social and environmental change. Routledge, Abingdon, United Kingdom.

Turnhout E, Lawrence A, Turnhout S. 2016. Citizen science networks in natural history and the collective validation of biodiversity data. Conservation Biology: in press.

Vallabh P, Lotz-Sisitka H, O’Donoghue R, Schudel I. 2016. Mapping epistemic cultures and learning potential of participants in citizen science projects. Conservation Biology: in press.

van der Wal R, Sharma N, Mellish C, Robinson A, Siddharthan A. 2016. The role of automated feedback in training and retaining biological recorders for citizen science. Conservation Biology: in press.

Wald DM, Longo J, Dobell AR. 2016. Design principles for engaging and retaining virtual citizen scientists. Conservation Biology: in press.

Wals AEJ, Brody M, Dillon J, Stevenson RB. 2014. Convergence between science and environmental education. Science **344**:583–584.

Wiggins A, Crowston K. 2011. From conservation to crowdsourcing: a typology of citizen science. Pages 1–10 in Proceedings of the 44th Hawaii international conference on system sciences. IEEE, New York.

Address correspondence to A.E.J. Wals, Wageningen University Department of Pedagogy, Professional Development and Didactics, University of Gothenburg, Sweden email arjen.wals@wur.nl

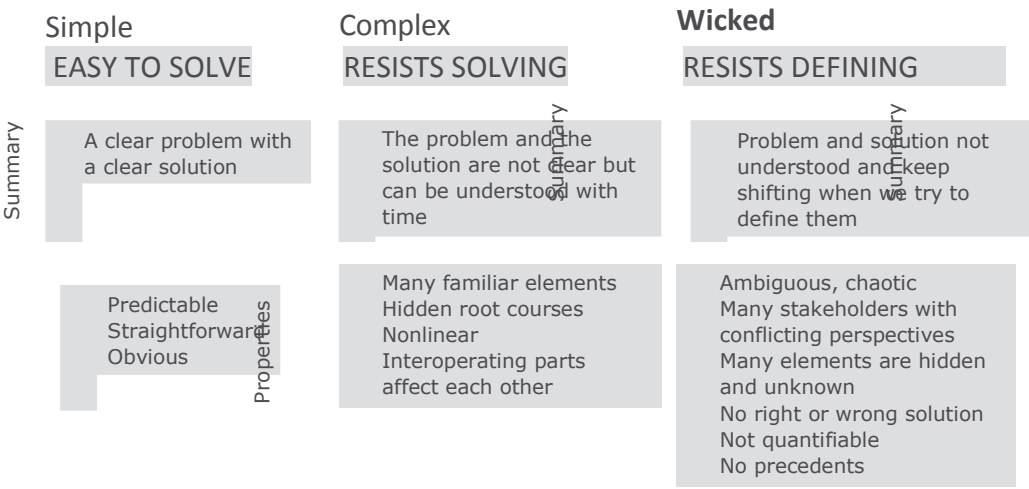


Figure 1. A typology of problems (Based on Gibson and Fox 2013).

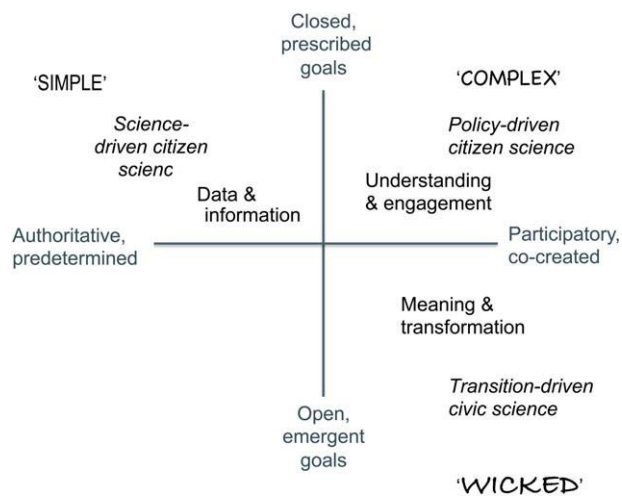


Figure 2. A heuristic of citizen science based on Wals and Jickling (2008).

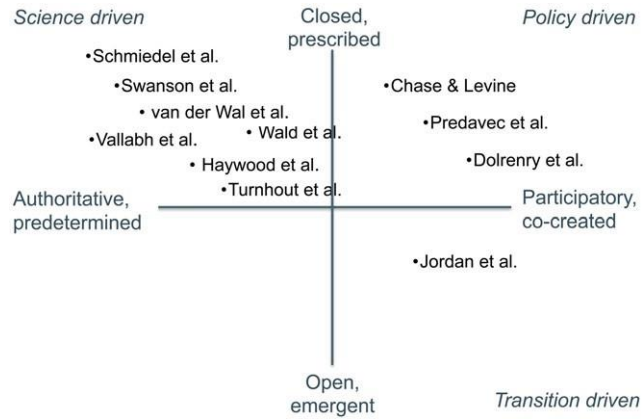


Figure 3. Position of the special-section articles in the heuristic in Fig. 2.